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Special Section

Rainbow in the Earth — Introduction

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Between 2003 and 2007, three scientific meetings were held under the "Rainbow in the Earth" banner in Oklahoma, U.S.A., California, U.S.A., and Scotland, U. K. The aim of the meetings was to bring together scientists from a diverse range of disciplines for a discussion around a common theme of scale and frequency dependence of geophysical properties.

The meetings have proven very successful, with attendees from academia and industry covering a full spectrum of topics, with an emphasis on exploration seismology and theoretical rock-physics modeling but including contributions on earthquake seismology, petroleum geology, and electromagnetic methods. This special section represents a selection of notable contributions to the first three meetings.

Upscaling

Scale-frequency issues are traditionally associated with upscaling problems, for example the difficulty of relating measurements taken at the seismic and log scales. This problem is tackled by Tiwary et al. who give an overview of current approaches to the problem. Helbig emphasizes the fundamental mathematical aspects of the problem, particularly the link between long-wavelength equivalent medium theories and scattering theory, which is valid when the wavelength approaches the scale length of the heterogeneities. This sets the scene for the paper by Silva and Stovas, who demonstrate a correspondence for a given layered velocity model between the anisotropic parameters, which would be inferred from propagation in both the low- and high-frequency limits. Slatt et al., in their paper, present a novel geologically based view on the upscaling problem .

Theory

Advances in laboratory measurements present a challenge to our theoretical understanding of dynamic rock properties, motivating the development of further rock physics models. Toms-Stewart et al. illustrate this process with an integrated study of the effect of gas-patch distribution in partially saturated rock on seismic attenuation. Jakobsen and Chapman show how the important concepts of squirt and global flow can be considered together in a consistent theoretical framework. Although attenuation is often closely related to the saturating fluid, it should be borne in mind that scattering is a powerful attenuation mechanism, as demonstrated by the modeling of Browaeys and Fomel.

Laboratory measurements

Laboratory measurements across a wide-frequency band have the potential to shed considerable light on the scale-frequency problem. McCann and Sothcott present an in-depth study of seismic attenuation in both sandstones and limestones for a variety of pressures and fluid saturations. The measurements are made with both resonant bar and ultrasonic techniques, allowing the frequency dependence of attenuation to be studied in detail. In a related paper, Fjær studies the differences in the static and dynamic elastic moduli of weak sandstone.

Case studies

The final area of study covered is the analysis of field seismic data for frequency-dependent effects. Sun et al. offer a direct study of VSP data to determine the magnitude of dispersion and attenuation, which may be expected in the seismic-frequency band. Reine et al. attempt to improve our estimates of attenuation from field data by studying the effects of various windowing techniques. The use of the continuous wavelet transform is a promising technique for deriving scale-dependent seismic attributes, as demonstrated by Sinha et al.

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Devi and Schwab present an intriguing method designed to recover high-resolution data from band-limited input using the scaling laws of the wavelet transform modulus maxima spectrum.

The papers in this special section have demonstrated once again that the geophysical properties we commonly deal with are scale and frequency dependent. Nevertheless, they also show that combining theoretical work with laboratory measurements and careful analysis of field data can provide us with significant insights into the underlying relationships. In this way, we hope that the scale-frequency dependence can evolve from a problem, related to the disagreement of various measurements, into a solution, whereby frequency dependence is itself measured and used to infer rock and fluid properties of interest. The fourth workshop, to be held in Boston, Massachusetts, U.S.A. in August 2009, surely will move us more in this direction.